

FABRICATION OF MEDIUM DENSITY FIBRE BOARD FROM OIL PALM
FROND USING WASTE LOW DENSITY POLYETHYLENE (LDPE)
COMPOSITES AS POSSIBLE PARTIAL REPLACEMENT FOR BINDER

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ABSTRACT

There are two objectives in this research. The first objective is to produce the high quality of medium density fibre board from waste biomass material, oil palm frond mixed with waste LDPE composites at the same time reducing the percentages of urea formaldehyde resin. The second objective is to characterize the physical and mechanical properties of fibre board. This research is very important to environment, it is one of the solution in order to reduce the emission of toxic formaldehyde from MDF. Different composition are use in order to produce the high fibre board in terms of strength and swelling effect. In industry, urea formaldehyde is use as a binder in fibre board manufacturing. In this research, the waste LDPE composite is selected as a possible partial replacement for binder in order to reduce the emission of toxic formaldehyde. Based on this research, the high quality fibre board can be produced which achieved the industrial requirement but strictly limited in its application.

ABSTRAK

Terdapat dua objectif dalam kajian ini. Objectif yang pertama adalah menghasilkan papan gentian berkualiti tinggi daripada sisa bahan biojisim iaitu dahan kelapa sawit yang dicampur dengan polietilina dalam masa yang sama mengurangkan peratusan urea formaldehid. Objectif kedua adalah untuk mengelaskan papan gentian dari segi fizikal dan mekanikal. Kajian ini sangat penting kepada alamsekitar, ia adalah salah satu cara untuk mengurangkan pembebasan toksik formaldehid daripada papan gentian. Komposisi yang berbeza digunakan untuk menghasilkan papan gentian terbaik dari segi kekuatan dan kesan terhadap air. Di industri, urea formaldehid digunakan sebagai bahan pelekat dalam pembuatan papan getian. Dalam kajian ini, sisa bahan polietilina berkepadatan rendah dipilih sebagai sebahagian daripada pelekat untuk mengurangkan pelepasan formaldehid yang bertoksik. Berdasarkan kajian ini, papan gentian yang berkualiti tinggi dapat dihasilkan yang mencapai tahap industri tetapi hanya boleh digunakan dalam aplikasi tertentu.

LIST OF ABBREVIATIONS

IB - Internal Bonding

LDPE - Low Density Polyethylene

MDF - Medium Density Fibreboard

MOR - Modulus of Rupture

OPF - Oil Palm Frond

SW - Swelling

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Frond, one of the largest waste from palm oil estate today. It is important to convert the waste to useful material. In addition to that, recycling the waste helps mitigate global warming and reduce deforestation activities. The amount of frond in Malaysia keep increasing every year due to a rapid expansion of its planted areas. In 2005, Malaysia produced more than 51 million tonnes of oil palm wastes particularly the empty fruit bunch (EFB), frond and trunk. (MPOB, 2006)

Various agricultural and municipal waste materials including municipal solid waste, biosolids, animal manures, yard trimmings, agricultural residues, waste paper, food processing wastes are composted as potting media without any negative effects on a variety of crops raised in these substrates (Inbar et al. 1986; Bugbee and Frink, 1989; Beeson 1996; Eklind et al. 2001; Hashemimajd et al. 2004).

Areas under oil palm increased from 54,000 hectares in 1960 to 4.05 million hectares in 2005, reflecting a compound annual growth of 10.06%. Production increased from 94,000 tonnes in 1960 to 15 million tonnes in 2005, or by almost 160 times within 45 years, this represents a compound annual growth of 11.93% per year. (Yusof Basiron, 2007)

Eight leaves (fronds) are produced in successive leaf spirals. Five spirals of leaves are retained on each mature tree. Leaf production rate is between 1 to 3 leaves per month. It grows up at low altitude which is less than 500 m above sea level, 15° from the equator in the humid tropics. Evenly distributed rainfall of 1,800 to 2,000 mm/year, but will tolerate rainfall up to 5,000 mm/year. Commercial palms have an economic life span of 20 to 30 years. (Better Crops International, 1999).

The oil palms comprise two species of the Arecaceae, or palm family. The African Oil Palm *Elaeis guineensis* is native to West and Southwest Africa, occurring between Angola and Gambia, while the American Oil Palm *Elaeis oleifera* is native to tropical Central America and South America. Mature trees are single-stemmed, and grow to 20 m tall. The leaves are pinnate, and reach between 3-5 m long. A young tree produces about 30 leaves a year.

This research also concerns about the huge amount of polymer waste around the world. Most light weight plastic packaging material is used for a one-time application and discarded when its useful life is over. These materials are durable and inert in the presence of microbes thus leading to a long term performance. (Arvanitoyannis, et al., 1998)

1.2 Problem of Statement

Now a days, up to 70 million tonnes per annum biomass collected in Malaysia. The massive amount of waste mainly comes from palm oil industry which contribute more than 80 percent. The increasing amount of waste around the world leads to environment problem such global warming due to burning of biomass. The wood fibre are the main component in fibre board manufacturing industries. The excess amount of wood fibre used in industry leads to deforestation problem.

There has been much awareness regarding the harmful effects of polymer materials on the environment. Recycling is obviously a better choice at a higher cost but most countries cannot afford to recycle all its polymer wastes. Moreover, all polymers are not recyclable since their properties after recycling are poor compared to their original ones and they are of less economic value (Narayan, 1990).

In Industry, normally urea formaldehyde is used as a binder. After a long period of time, the composites wood products will emit the toxic formaldehyde to the air. The emission of toxic formaldehyde to environment is harmful to human health. It is very important to reduce or replace the used of urea formaldehyde with other type of binder which are safe to environment and economic.

In the mid 1980s the forest cover of Borneo was still at 75%. In 2005 only 50% of Borneo remained under forest cover. Between 1985 and 2005 Borneo lost an average of 850,000 ha of forest every year. If this trend continues, forest cover will drop to less than a third by 2020. The rate of deforestation in Kalimantan (the

Indonesian part of Borneo) is increasing. Between 2000 and 2002 deforestation rose to 1.2 million ha a year. Together with the forest loss in Sabah and Sarawak (the Malaysian part of Borneo) this would amount to a total forest loss of 1.3 million ha a year. This is the equivalent of 148 ha every hour, 2.5 ha a minute. (Mario Rautner *et al.*, 2002)

1.3 Objectives of Research

- i. To produce the high quality of medium density fibre board from waste biomass material, oil palm frond mixed with waste LDPE composites at the same time reducing the percentages of urea formaldehyde resin.
- ii. To characterize the physical and mechanical properties of fibre board.

1.4 Scope of Research

In order to achieve the objectives, several scopes has been identified.

- i. Using different composition of fibre board to produce high quality fibre board.
- ii. Observe the swelling effect towards the increase in thickness of fibre board.
- iii. Test the strength of fibre board with universal testing machine.

CHARTER 2

LITERATURE REVIEW

2.1 Oil Palm Frond (OPF)

Increase of industrial activities causing an ascending accumulation of different types of wastes such as frond which come from palm oil estate. According to MPOB on 2006, the oil palm frond was produced 26.2 million tonnes per annum from palm oil industries in Malaysia. OPF is one type of the fibre that can be use to produce fibre board in industry.



Figure 2.1.1: Oil Palm Frond (OPF)

Malaysia is currently the world's largest producer and exporter of palm oil. The plantation sector dates back to 1896, with the start of the rubber industry. Oil palm cultivation began in 1917, but growth was initially very slow. It was only during the last 50 years that plantation development was accelerated through large-scale investments in the cultivation of the oil palm as one of the approved crops for diversifying the country's agricultural development. (Yusof Basiron, 2007)

The availability of fronds during the pruning activity was calculated using estimate of 10.4 tonnes ha⁻¹, which currently gives an average of 6.97 million tonnes per year. Meanwhile, it was estimated at an average of 54.43 million tonnes per year of OPF will be available during the replanting process in the years of 2007 – 2020. (Oil Palm Biomass, 2009)

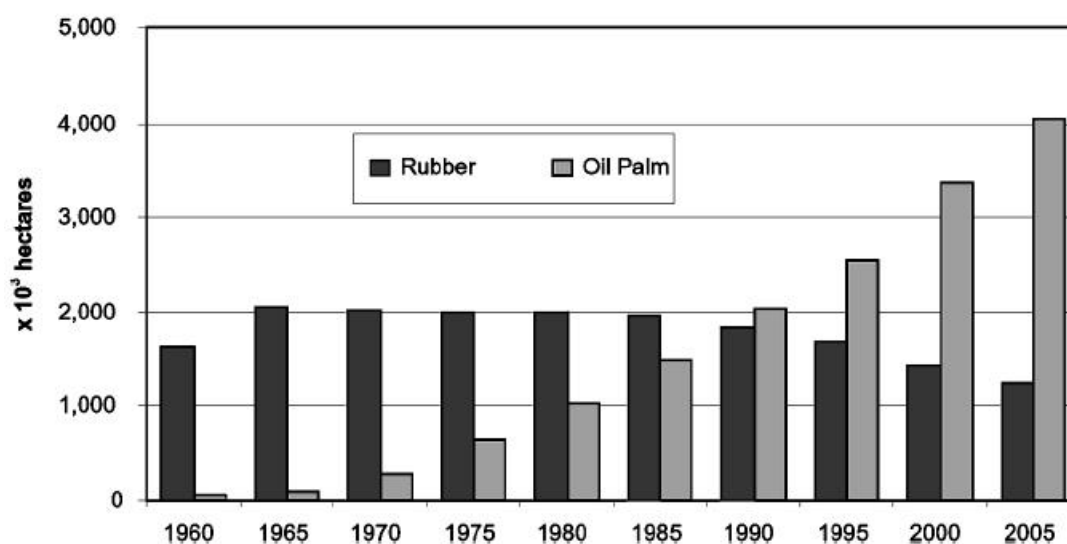


Figure 2.1.2: Planted area for oil palm and rubber in Malaysia.
(Source: MPOB, Malaysian Rubber Board)

Chemically, the frond strands are rich in holocellulose (83.5%) and also high in α -cellulose (49.8%), both of which are important parameters in determining the suitability of a raw material for papermaking (Ona et al., 2000). As a comparison, the data from Canadian aspen (*P. trem.*) is also included. The lignin content (20.5%) is lower than normally found in common hardwood, for example aspen of 18.1% (Law and Jiang, 2001) and eucalyptus of 22% (Alcaide et al., 1990)

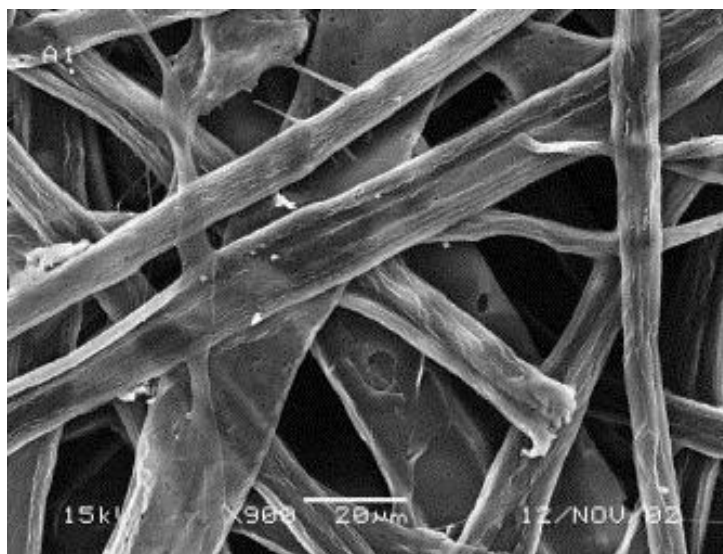


Figure 2.1.3: SEM of oil palm frond
(Source: W.D. Wanrosli *et. al.*, 2007)

2.2 Toxic Formaldehyde

Formaldehyde is a suspected human carcinogen that is known to be released from pressed-wood products used in home construction, including products made with urea-formaldehyde resins (Kelly *et al.*, 1999; Otson and Fellin 1992). Emissions have resulted in various symptoms, the most common of which is irritation of the eyes and the upper respiratory tract (Pickrell *et al.*, 1986).

2.3 Medium Density Fibreboard (MDF)

MDF (Medium Density Fibreboard) was developed in the United States and has since 1973 been produced in Europe, where it achieved an effective breakthrough only in the 1990s. For MDF boards, the weight by volume varies from 450 to 800 kg/m³. (Spanolux, Wood Based Solutions). MDF is denser than plywood. It is made up of separated fibres, but can be used as a building material similar in application to plywood. It is stronger and much more dense than normal particle board.



Figure 2.3.1: Medium Density Fibreboard

In the case of MDF boards, the weight by volume is not constant across the thickness and across the width (and to a lesser extent across the length) of the board. The press can be set for the production of MDF with high or low densified cover layers. MDF is produced in various types and qualities.

In terms of weight by volume, MDF can be classified as follows:

- HDF: 800 kg/m³
- MDF: 650-800 kg/m³
- Light MDF: 550-650 kg/m³
- Ultralight MDF 450-550 kg/m³

2.4 MDF Manufacturing

Medium Density Fibreboard (MDF) is an engineered wood product formed by breaking down hardwood or softwood residuals into woodfibres, often in a defibrator, combining it with wax and a resin binder and forming panels by applying high temperature and pressure (Spence, 2005). MDF is manufactured using the dry process in which the wood fibres are mixed with resin and pressed in dry condition. The weight by volume represents the mass per unit of volume.



Figure 2.4.1: MDF Manufacturing in Industry

In industry, there are several types of thermosetting resin that is used as a binder such as Urea Formaldehyde (UF) and Phenol Formaldehyde (PF). The wood fibre is dried so that the moisture content is less than 10 percents. Then, the wood fibre is blend and spray properly with resin for a few minutes before it is press in high temperature at certain period of time.

2.5 Moisture Content in MDF

After production, MDF has a moisture content of $8 \pm 3\%$. At the time of delivery to the end-user, however, the moisture content may have altered due to ambient factors during transport and storage. In particular, storing the panels in a humid environment on the construction site will inevitably lead to water absorption. Conversely, the moisture content will decrease in a very dry environment. (Spanolux, Wood Based Solutions). During the blending, chemical spray and pressing, the moisture content of wood fibre should be less than 10 percents.

2.6 Board Testing

2.6.1 Modulus of Rupture

Modulus of Rupture (MOR) is the maximum force necessary to break a specimen of specified width and thickness. According to Andreas in 2007, MOR is an accepted criterion of strength, although it is not a true stress because the formula by which it is computed is valid only to the elastic limit. Figure 2.6.1 show the 3-point bending test for MOR according to European standard EN310.

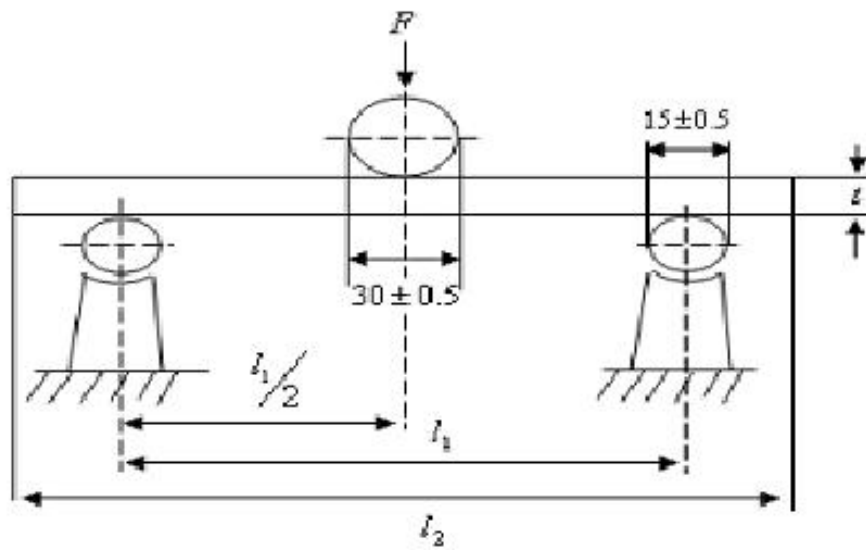


Figure 2.6.1: 3-Point Bending Test

Another European Standard that can be used to test the MOR is EN789. This testing method is called 4-point bending test. EN789 is quite different compared to EN310 which is, two directions of force are applied against the sample at the same time. On the other hand, only one direction of force is applied against the sample. Based on study by S.F. Tsen and M. Zamin Jumaat in 2011, tested under EN310 had MOR larger and MOE smaller than EN789.

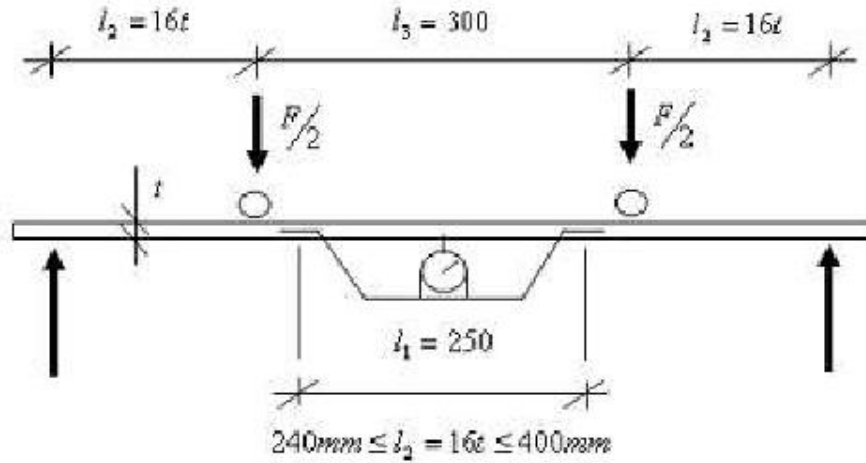
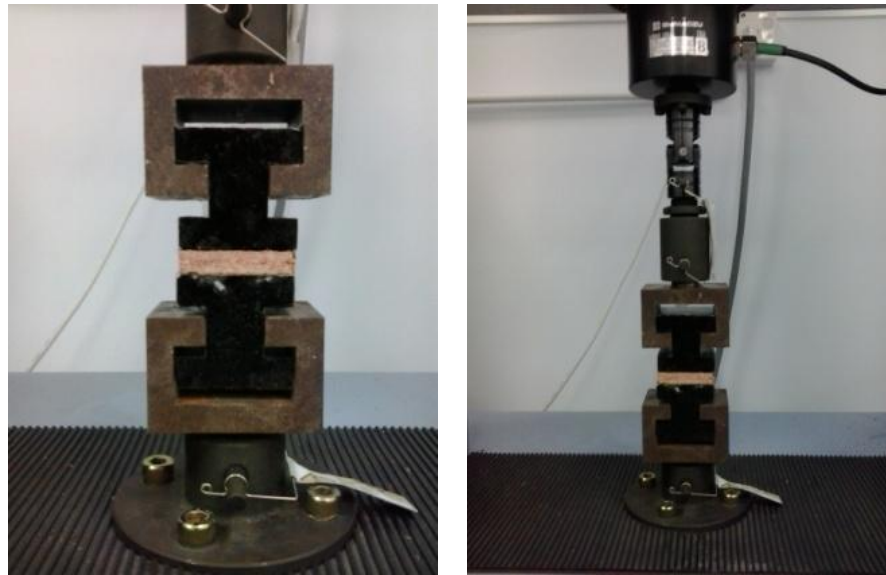


Figure 2.6.2: 4-Point Bending Test

2.6.2 Internal Bonding

The Internal Bonding (IB) is the strength perpendicular to the plane of the board. This testing on board provides direct information on the adhesion of the wood particles. In this testing, special block should be glue with the sample before it can be fit in the testing machine. The European Standard EN319 is used in this test. Figure 2.6.2 (a) and (b) show the internal bonding test with block.



(a)

(b)

Figure 2.6.2: The Internal Bonding Test

2.6.3 Thickness Swelling

In swelling test, the effect of water on MDF can be investigate by the different in thickness of MDF after immersed in water for 24 hours. The percentage of swelling can be calculated based on the different in thickness. In this research, The swelling test is conducted according to European Standard EN317.

2.7 Universal Testing Machine

Universal testing machine is one of the important equipment use in this research. The mechanical properties features of wood based panels can be easily and precisely determined. Measurement can be carried out according to European Standards (EN), for the measurement of internal bond strength, according to

alternative testing methods. The alternative measuring methods supply the results within a few minutes.



Figure 2.7.1: Universal Testing Machine

2.8 Hot Molding Place

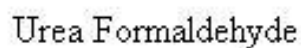
Hot molding place is the equipment which shape the fibre board according to the target thickness. The sample is pressed with high pressure and temperature. The blending sample is pressed by two heated plate. The temperature of upper and lower pressing plate in this equipment can be set manually according to requirement. In addition, the pressure and time of pressing also can be set.



Figure 2.8.1: Example of Hot Molding Place

2.9 Urea Formaldehyde

Urea formaldehyde (UF) is the common type of resin use in industry. It is available in liquid and powder form. Urea formaldehyde is a synthetic resin, it is obtained by chemical combination of urea and formaldehyde. Formaldehyde is a highly reactive gas obtained from methane while the urea is a solid crystal obtained from ammonia. Urea-formaldehyde resins are used mostly as adhesives for the bonding of plywood, particleboard, and other structured wood products. In this research, urea formaldehyde in liquid form is used as a binder. The density of UF is around 1.282 g/cm^3 .



2.11 Low Density Polyethylene (LDPE)

LDPE represents the majority of thermoplastics currently used as food packaging materials. Since the production and consumption of these polymers is incessantly increasing (Behjat Tajeddin *et al.*, 2009). There are different types of polymers: natural polymers (for example wool, silk, wood, cotton), half synthetic polymers (natural polymers which are chemically modified, for example casein plastics, cellulose plastics) and synthetic polymers (27, TWGComments, 2004).

Worldwide production of plastics is more than 78 million tons per year and almost half of that is discarded within a short time, remaining in garbage deposits and landfills for decades (more than 30 years) (Volke-Sepulveda *et al.*, 1999). Polymer companies produce a variety of basic products, which range from commodities to high added-value materials and are produced in both batch and continuous processes covering installations with a capacity of some 10000 tonnes per year up to some 300000 tonnes per year.

The underlying building principle is very flexible so that polymers with an extensive range of properties and property combinations can be produced. Polymers in the shape of objects, fibres or films may be:

- Rigid or flexible.
- Transparent, translucent or opaque.
- Hard or soft.
- Weather resistant or degradable.
- Resistant to either high or low temperature.

In addition, they may be compounded with fillers, blended with other products (e.g. glass fibres) forming so-called composites or with other polymers yielding polymer blends. Alternative materials exist and polymers have to be successful in a competitive market. Polymers often bring advantages to numerous applications, for example:

- Weight reductions and consequent transport and fuel savings.
- Electrical insulating properties suitable for wiring, switches, plugs, power tools and electronics.
- Optical transparency suitable for packaging, lighting and lens applications.
- Corrosion resistance which is important for plumbing, irrigation, rainwear and sports articles.
- Resistance to chemicals, fungi and mildew.
- Ease of processing making complicated shapes possible.
- Cost savings over alternative solutions.

(Best Available Techniques in the Production of Polymers, 2007)

LDPE has more branching (on about 2% of the carbon atoms) than HDPE, so its intermolecular forces (instantaneous-dipole induced-dipole attraction) are weaker, its tensile strength is lower, and its resilience is higher. Also, since its molecules are less tightly packed and less crystalline because of the side branches, its density is lower. LDPE contains the chemical elements carbon and hydrogen.